NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1753

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SUMMARY

An investigation was made in the Langley gust tunnel to determine the effectiveness of a fixed spoiler, forwardly located upon the upper surface of a wing, in reducing the loads imposed upon airplanes in flights through gusty air. Flights of an airplane model were made through a sharp-edge and a gradient gust with and without the spoilers attached. The results indicate that the model undergoes approximately the same maximum acceleration with or without the spoilers in a sharp-edge gust. In a gust with a gradient distance of 12 chords, a reduction of 30 percent in the maximum acceleration increment was realized through the use of the spoilers.

INTRODUCTION

One of the many devices which has been proposed for use in reducing the acceleration effects of a gust is the spoiler. Wind-tunnel tests (reference 1) indicate that an upper-surface spoiler may, if properly placed, reduce the slope of the lift curve as much as 65 percent, the reduction in slope causing a possible corresponding reduction of the gust load increment.

The spoiler, because of the small forces involved in its operation and its simplicity of construction and installation, is attractive as a gust alleviator. Spoilers may be used in a system which is automatically regulated by some gust reaction, or they may be manually controlled so as to be extended to a fixed position by the pilot whenever rough air is anticipated. Their use in either form is questionable because of the inherent aerodynamic lag in the response of spoilers, and also, because of the possible difficulty of obtaining proportional effects in a spoiler system. The effect of aerodynamic lag is probably greatest for the automatic spoiler because the lag of an abrupt change in angle of attack is combined with that of the sudden movement of the spoiler. The use of a fixed spoiler could possibly reduce this lag and produce more nearly the alleviating effect which would be predicted from steady-flow data.

Since the applicability of steady-flow results to the transient conditions of a gust entry is dubious, tests were made in the Langley gust tunnel to investigate the effectiveness of a fixed spoiler as a gust alleviator.

METHOD AND APPARATUS

The method of testing consisted of flying a model with and without the spoilers attached through gusts of known shape and of comparing the measured reactions of the model which were obtained from the two test conditions.

The present Langley gust tunnel is similar in principle to the one described in reference 3, and the capacity of the equipment now used is described in reference 2. The gust shapes are obtained by means of screening and perforated plates placed in the tunnel jet. Two gust shapes were chosen for the test: an extreme or sharp-edge gust, and a gust with a gradient distance of 12 chords, which is within the range of gradient distances considered most applicable in design requirements. These shapes are shown in figures 1(a) and 1(b).

A photograph of the test model with the spoilers attached is shown in figure 2, and a plan-view line drawing with the spoiler detail is shown in figure 3. The pertinent characteristics of the model, which employed the NACA 0012 airfoil as the basic wing section, are listed in table I.

The spoilers, which consisted of $\frac{3}{32}$-inch-thick balsa strips, were 2.5 percent of the local chord c in height and extended along 90 percent of the wing span. They were mounted perpendicular to the upper surface of the wing at a position 12 percent of the local chord aft of the leading edge of the wing as shown in figure 3. The spoiler-wing joint was sealed, and several small braces were placed against the rearward side to insure a reasonable amount of stiffness.

The model was fitted with a recording accelerometer and carried small lights in the nose and tail from which the flight path and attitude of the model could be determined.

TESTS

Test flights of the model, with and without the spoiler attached, were made at one weight, one center-of-gravity position, and one forward speed through a sharp-edge gust and a gust with a gradient distance of 12 chords. A total of 30 flights were made, 15 of which were made with the spoiler; the number of flights was about equally divided between the two gust shapes shown in figures 1(a) and 1(b). A forward speed of 88 feet per second and a maximum gust velocity of 10 feet per second were used throughout all tests.

Measurements of the forward speed, gust velocity, normal-acceleration increment, and pitch-angle increment were recorded for each flight.

RESULTS

The normal-acceleration and pitch-angle records for each flight were evaluated to obtain histories of events for both the sharp-edge and gradient gusts. Sample histories for each test condition and for both gust shapes are shown in figures 4(a) and 4(b). The maximum acceleration increment for each flight was obtained from the time histories and was corrected for minor variations from the specified test conditions on the assumption that the values of acceleration are directly proportional to the forward velocity and gust velocity. (See reference 3.) Average maximum corrected values of the acceleration increment obtained from all tests are given in table II. The maximum acceleration increments for each flight were then reduced to zero pitch by the approximate method of equation (3) of reference 2. The resulting average values of the maximum acceleration increments for all test conditions are included in table II.

PRECISION

The measured quantities are estimated to be accurate within the following limits for any test:

Acceleration increment Δn, g units	±0.05
Forward velocity V, feet per second	±0.5
Gust velocity U, feet per second	±0.1
Pitch-angle increment $\Delta\theta$, degrees	±0.1

In addition to errors in the measured quantities, slight variations in the attitude of the model during launching and small changes in the atmospheric conditions may introduce scatter in the test results. The probable errors, which are a measure of this scatter (reference 4), are included in table II and have a maximum value of about 4 percent. The minor differences in gust shapes, as shown by figures 1(a) and 1(b), were disregarded in this analysis.

DISCUSSION

Inspection of the sample time histories of events, together with the experimental values of the maximum acceleration increments as given in table II, indicates that while the spoiler had no alleviating effect in the sharp-edge gust, the alleviation amounted to 30 percent for a gust with a gradient distance of 12 chords. Further examination of the histories shows that the spoiler caused appreciable pitching motion in the gusts, but the incremental angle of pitch was small at the time of maximum acceleration, and the correction for its effect did not radically change the acceleration increments, as indicated in table II.

From examination of figure 4(a), it is evident that after maximum acceleration has been reached in the sharp-edge gust, the spoiler becomes effective in reducing the acceleration which the model undergoes. This delayed reduction in acceleration would indicate that a definite time passes before the flow breakdown is accomplished after the rapid change in angle of attack. In the gradient gust, however, the lag is overcome in time for the spoiler to produce an alleviating effect upon the maximum acceleration. The exact extent of the lag cannot be determined from these tests.

Further inspection of table II shows that, in the sharp-edge gust, the maximum accelerations were slightly higher with the spoiler in place than without the spoiler. The additional acceleration of the model with the spoiler might be attributed to the fact that the spoiler serves to increase the camber of the airfoil during the first penetration of the gust.

The results of preliminary wind-tunnel tests, made to determine the trim and performance of the test model, showed that within the range of angle of attack associated with steady flight and penetration of a gust, the spoiler produced a nonlinear lift curve of three different slopes, each of which was lower than the slope for the clean condition. During the rapid change in angle of attack caused by the penetration of a gust, it is possible that the development of lift would not follow the same broken lift curve as in the steady-state condition, except for the longer gust-gradient distances. The alleviation, or reduction of the acceleration increment caused by the spoiler, was calculated for the three lift-curve slopes by use of equation (4) of reference 5 for a gust with a gradient distance of 12 chords. A comparison of these results with the experimental data indicates that the lift-curve slope corresponding to flight prior to the gust entry is the most appropriate for prediction of alleviation. Because of the limited data, however, this evidence cannot be considered conclusive.

The present data show that an upper-surface, fixed spoiler would be useful as a gust alleviator in up gusts having gradient distances of approximately 12 chords. In larger gradient gusts, in which the flow conditions are approaching more nearly a condition of steady state, the spoiler should be as effective as in the 12-chord gust. From the results obtained in the sharp-edge gust, however, and from the nature of the flow breakdown and its effect upon the acceleration increment as shown by figure 4(b), the alleviation effect of fixed spoilers is thought to decrease for gusts with gradient distances less than 12 chords.

Since this test covered only the possibilities of a positive or up gust, the results produced by the use of a fixed spoiler under the action of a negative gust are subject to conjecture. In a down gust, it is probable that the forward spoiler would be operating in a region in which the subpressure of the airfoil was decreasing, and hence would not be so effective as in the up gust.

CONCLUDING REMARKS

The results of an investigation made in the Langley gust tunnel to determine the effectiveness of a fixed spoiler as a gust alleviator indicate that for the conditions tested the use of a fixed spoiler had no effect upon reducing the maximum acceleration which the model undergoes in a sharp-edge gust. The reduction in lift due to the spoiler flow breakdown was accomplished after maximum acceleration had been reached. In a gust with a gradient distance of 12 chords, the use of the spoiler resulted in a 30-percent reduction of the maximum acceleration increment.

Langley Aeronautical Laboratory
National Advisory Committee For Aeronautics
Langley Field, Va., September 8, 1948

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TABLE I

CHARACTERISTICS OF TEST MODEL

Weight, lb	9.31
Wing area, sq ft	5.45
Aspect ratio	6.6
Wing loading, lb per sq ft	1.71
Span, b, ft	6.00
Mean geometric chord, ft	0.905
Center-of-gravity position, percent mean geometric chord	27.0
Height of spoiler, percent wing chord	2.5
Span of spoiler, percent wing span	90.0
Spoiler location, percent wing chord from L.E.	12.0

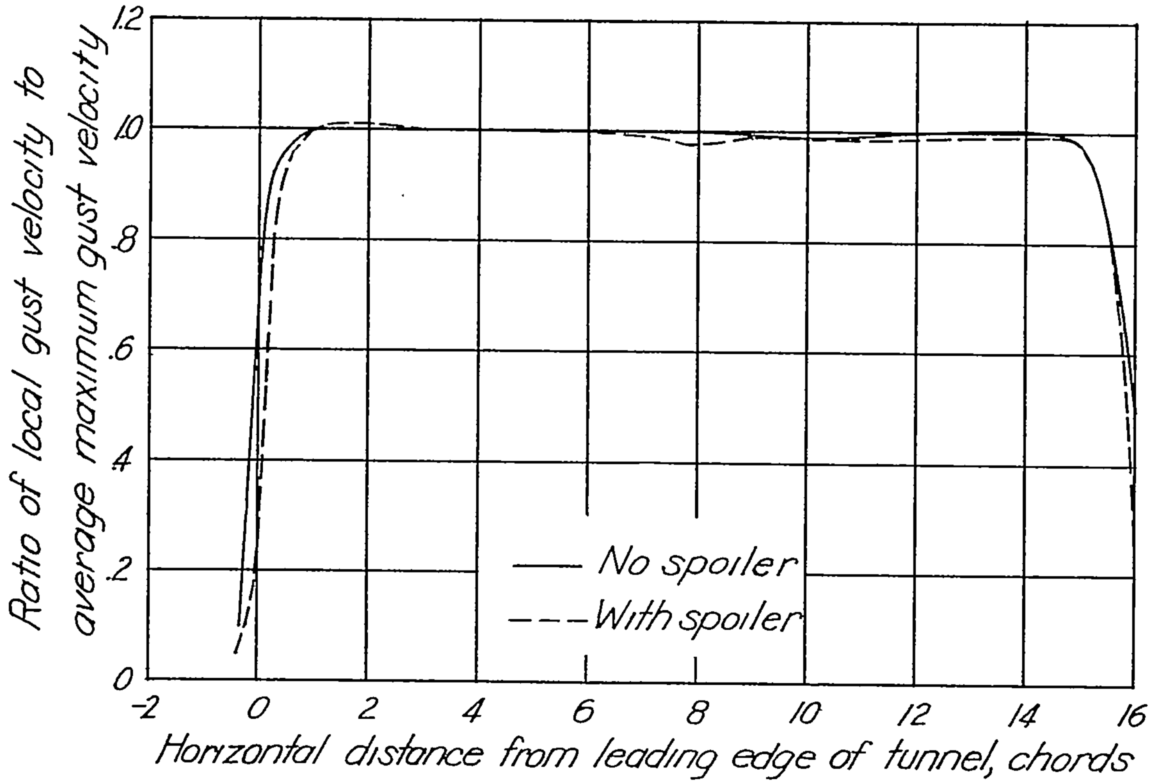
TABLE II

EXPERIMENTAL MAXIMUM ACCELERATION INCREMENTS

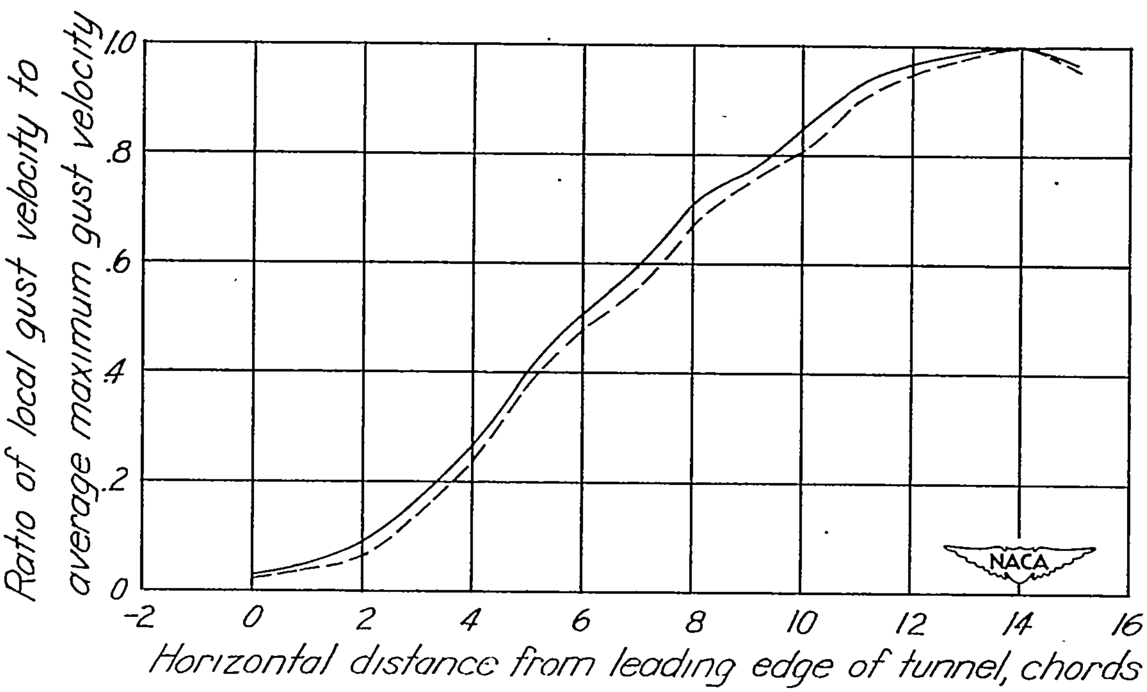
[Average of all flights]

Gust shape	Experimental Δn_{max} (g units)		Experimental Δn_{max}, reduced to zero pitch (g units)	
	Without spoiler	With spoiler	Without spoiler	With spoiler
Sharp-edge	2.06 ± 0.03	2.19 ± 0.05	2.05 ± 0.03	2.15 ± 0.05
Gradient (12 chords)	1.60 ± 0.03	1.13 ± 0.04	1.64 ± 0.03	1.15 ± 0.04

NACA



(a) Sharp-edge gust.



(b) Gust with 12-chord gradient distance.

Figure 1.- Velocity distribution of test gusts.

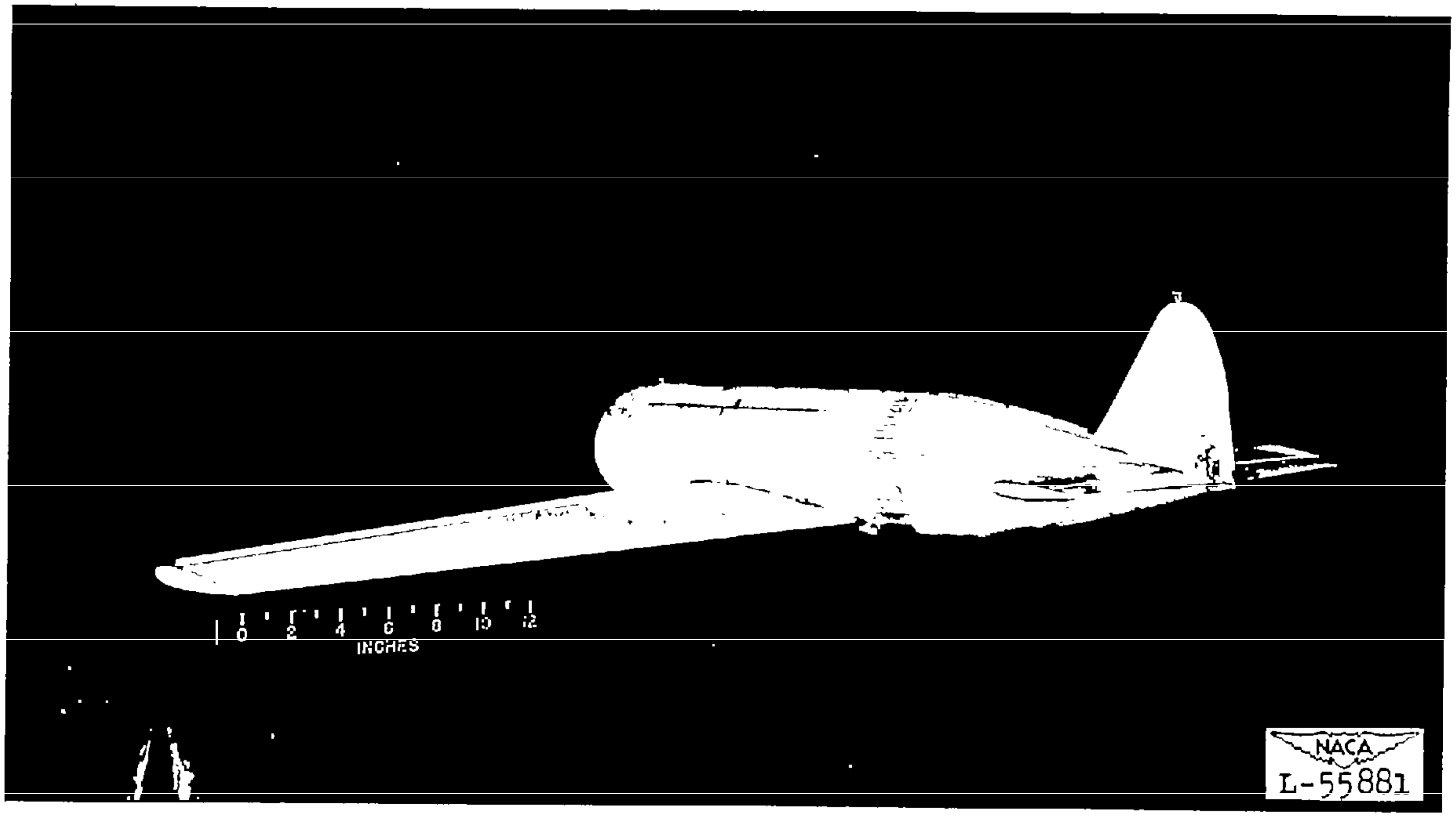


Figure 2.- Airplane model.

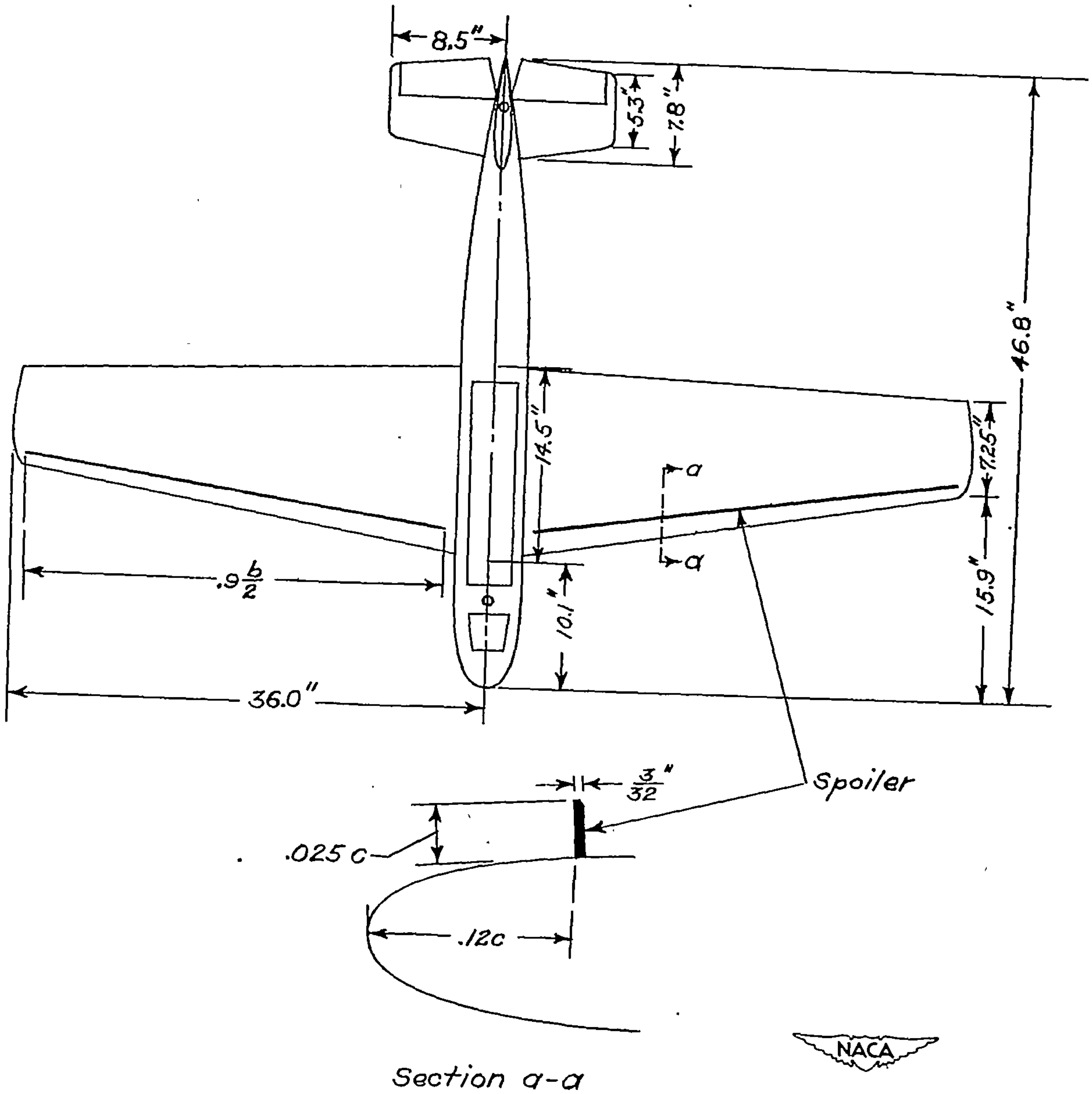
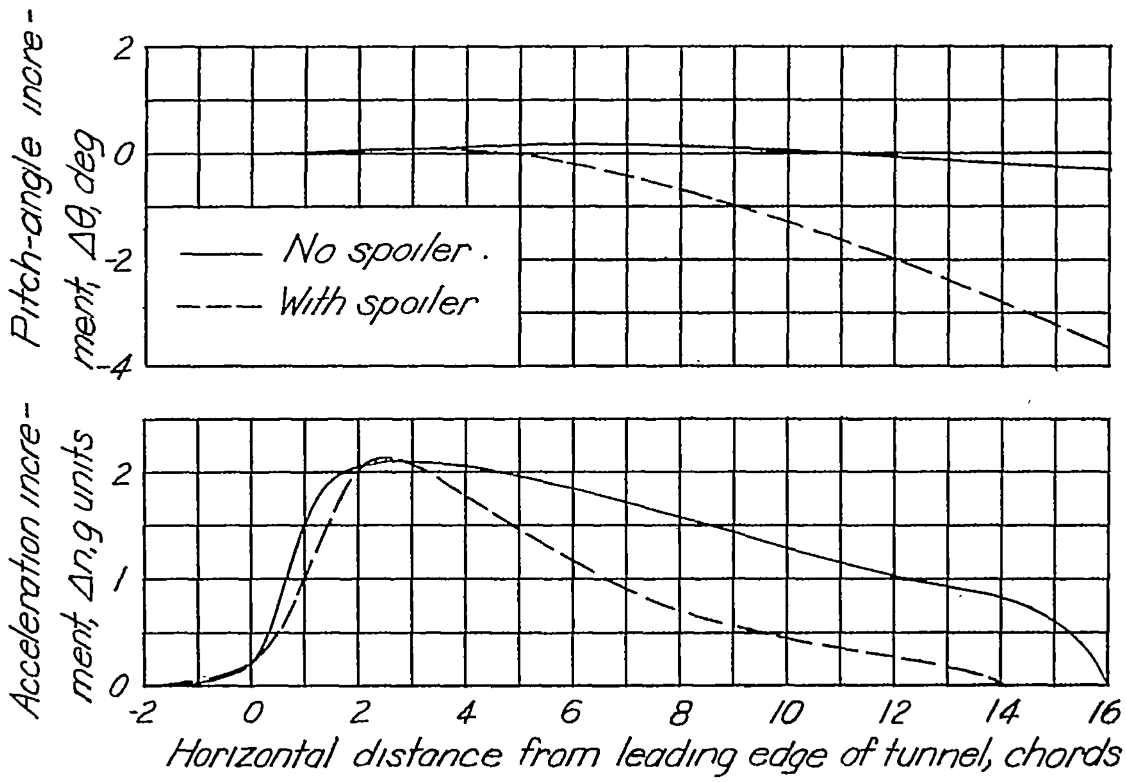
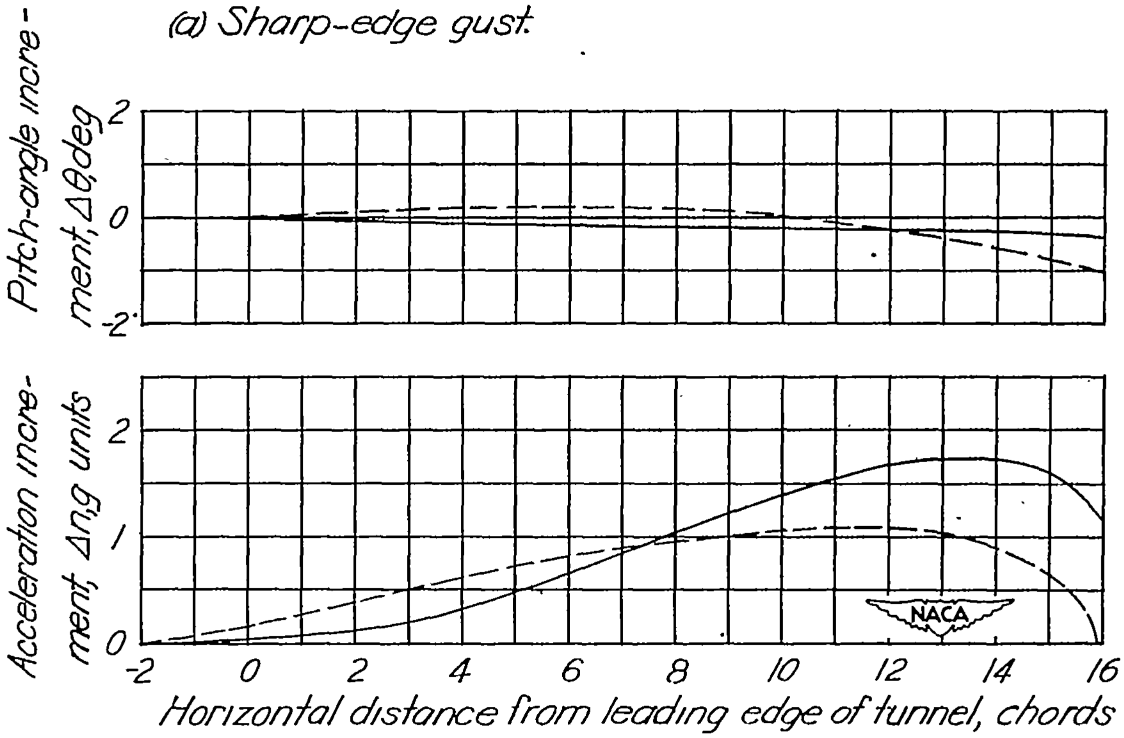


Figure 3.- Test model with spoiler detail.



(a) Sharp-edge gust.



(b) Gust with 12-chord gradient distance.

Figure 4.- History of events in test gusts.